



Attorney Docket No.: 09613/000M947-US0

Statement of Accuracy

U.S. Patent Application Serial No. 10/625,474 filed July 22, 2003

ZOOM LENS

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The undersigned,

Minoru MOCHIZUKI

certifies:

(1) I am fully conversant with both the English and the Japanese languages;

(2) I translated into English:

Japanese Patent Application No. 2002-212232

(3) I certify the accuracy of the English translation of the above-identified Japanese application provided herewith in that it was done to the best of my knowledge and ability.

Date: May 18, 2005

Signature Minoru Mochizuki



9613/0M947

Word count: 5,332

Specification

Title: ZOOM LENS

Field of the invention

The present invention relates to a zoom lens suitable for small digital still cameras, video cameras and the like equipped with image pickup devices such as CCD and the like, in particular, a zoom lens suitable for small digital still cameras, video cameras and the like built into cellular telephones, portable information terminals (PDA), etc.

Prior Art

In recent years, due to remarkable technical advancements in solid state image pickup devices for uses in digital still cameras, video cameras and the like, small CCD and similar devices are developed and, with it, a demand of smaller and lighter optical systems are in great demand.

In particular, there is a need for smaller and thinner optical systems to be used on cellular telephones and portable information terminals as they become smaller and thinner. The optical systems used on the cellular telephones and portable information terminals of the prior art have been relatively small and suitable for demands for smaller and thinner units because they were fixed focal point lens systems.

In order to have a zoom lens that provides variable magnifying power on a cellular telephone and a portable information terminal where a smaller and thinner unit is mandatory, it is possible to have a plurality of lens barrels that are arranged to be able to slide in and out and cause them to collapse into the body when it is not in use in order to make the system thinner, the constitution of the lens barrels including the collapsible mount mechanism becomes more complex and the number of components increases.

In order to improve the above situation, the present invention intends to provide a small, thin, and lighter zoom lens having a high quality optical capability suitable for being used on cellular telephones and portable information terminals, more specifically, a zoom lens having a zoom ratio of 2 or so, a depth direction stroke in the incidence direction of the object light between the in-use and the not-in-use (stored) conditions is less than 9 mm, and the longest dimension when it is in-use is less than 27 mm.

Summary of the invention

The zoom lens of the present invention comprises: a first lens group having a negative refractive power as a whole, a second lens group having a positive refractive power as a whole, and a third lens group having a positive refractive power as a whole, arranged in said order from object side to image plane side, for zooming from a pantoscopic end to a telescopic end as well as correcting image plane changes required in accordance with said zooming by means of moving said second lens group and said third lens group from image plane side to objection side; wherein said first lens group consists of a lens having a negative refractive power and a prism for changing a light path arranged in said order from the object side.

Since the depth dimension of the zoom lens according to said constitution is the depth dimension in the direction the object light enters into the first lens group (a lens and a prism), it is possible to obtain a thin and small zoom lens wherein the depth dimension and the dimension between the first lens group to the image plane remain constant regardless of whether it is used or not for shooting.

In the above constitution, it is possible to adopt such a constitution wherein the second lens group consists of a lens with a positive refractive power and an aperture stop exists between the second lens group and the third lens group. In this constitution, the total length in the optical axis direction becomes shorter and the lens groups on both sides (located on the upstream side and the downstream side) of the aperture stop can be formed in such a way as to have approximately identical external dimensions, so that the zoom lens can be made more compact efficiently.

In the above constitution, it is possible to adopt such a constitution wherein the lens of the first lens group has an aspherical surface, the aspherical surface is formed on the surface with a smaller radius of curvature, and the negative aspherical surface has a negative refractive power weakening toward its periphery. According to these constitutions, a better optical characteristic can be achieved as various aberrations can be easily corrected by having an aspherical surface, and distortion can be more easily corrected by having the aspherical surface on the surface with a smaller radius of curvature and forming it in such a way as to make the negative refractive power weaken toward the periphery.

In the above constitution, said third lens group can be constituted to have at least one lens with a positive refractive power and at least one lens with a negative refractive power. According to said constitution, various aberrations can be corrected with a better balance.

In the above constitution, said third lens group can be constituted to have a lens at a position closest to the object having a positive refractive power and an aspheric surface at least on one side. According to said constitution, spherical aberration can be corrected most suitably.

In the above constitution, the prism of said first lens group can be formed to have an entrance surface and an exit surface both oblong in a direction perpendicular to a plane that includes an entrance axis and an exit axis. According to this constitution, the zoom lens can be made thinner in the direction the object light enters (the direction of the optical axis from the first group's lens to the prism).

In the above constitution, it is possible to adopt a constitution that satisfies the following conditional formulas (1) and (2):

$$(1) \quad 0.25 < |fw/f1| < 0.7,$$

$$(2) \quad v1 > 40,$$

where $f1$ is the focal distance of the first lens group, fw is the focal distance of the total lens system at the pantoscopic end, and $v1$ is the Abbe's number of the first lens group's lens.

According to this constitution, if the value of $|fw/f1|$ in the conditional formula (1) exceeds its lower limit, the refractive power of the lens of the first lens group becomes too small, so that a necessary back focus cannot be achieved; on the other hand, if it exceeds the upper limit, the back focus becomes too large, so that it becomes difficult to make the unit smaller as well as to correct astigmatism and coma aberrations. Therefore, by satisfying the conditional formula (1), a better optical characteristic and size reduction can be achieved. Also, by satisfying the conditional formula (2), chromatic difference of magnification can be corrected appropriately.

In the above constitution, the first lens group, the second lens group, and the third lens group can all be made of resin materials. This constitution makes it possible to manufacture easily, to reduce the manufacturing cost and to reduce the weight.

Brief description of the drawings

Fig. 1 is a constitutional drawing showing an embodiment of a zoom lens according to the present invention.

Fig. 2 (a) and (b) show the status vies of the zoom lens shown in Fig. 1 at its pantoscopic end and telescopic end.

Fig. 3 is a perspective view of the zoom lens shown in Fig. 1.

Fig. 4 shows aberration charts of spherical aberration, astigmatization, distortion, and chromatic difference in magnification at the pantographic end of the zoom lens according to embodiment 1.

Fig. 5 shows aberration charts of spherical aberration, astigmatization, distortion, and chromatic difference in magnification at a middle position of the zoom lens according to embodiment 1.

Fig. 6 shows aberration charts of spherical aberration, astigmatization, distortion, and chromatic difference in magnification at the telescopic end of the zoom lens according to embodiment 1.

Fig. 7 is a constitutional drawing showing another embodiment of a zoom lens according to the present invention.

Fig. 8 (a) and (b) show the status vies of the zoom lens shown in Fig. 7 at its pantoscopic end and telescopic end.

Fig. 9 shows aberration charts of spherical aberration, astigmatization, distortion, and chromatic difference in magnification at the pantographic end of the zoom lens according to embodiment 2.

Fig. 10 shows aberration charts of spherical aberration, astigmatization, distortion, and chromatic difference in magnification at a middle position of the zoom lens according to embodiment 2.

Fig. 11 shows aberration charts of spherical aberration, astigmatization, distortion, and chromatic difference in magnification at the telescopic end of the zoom lens according to embodiment 2.

Fig. 12 is a constitutional drawing showing yet another embodiment of a zoom lens according to the present invention.

Fig. 13 (a) and (b) show the status vies of the zoom lens shown in Fig. 12 at its pantoscopic end and telescopic end.

Fig. 14 shows aberration charts of spherical aberration, astigmatization, distortion, and chromatic difference in magnification at the pantographic end of the zoom lens according to embodiment 3.

Fig. 15 shows aberration charts of spherical aberration, astigmatization, distortion, and chromatic difference in magnification at a middle position of the zoom lens according to embodiment 3.

Fig. 16 shows aberration charts of spherical aberration, astigmatization, distortion, and chromatic difference in magnification at the telescopic end of the zoom lens according to embodiment 3.

Description of numerical keys used in the drawings
I First lens group

II	Second lens group
III	Third lens group
1	Lens (first lens group)
2	Prism (first lens group)
2a	Entrance surface
2b	Exit surface
L1	Entrance axis
L2	Exit axis
3, 3', 3''	Lens (second lens group)
4, 4', 4''	Lens (third lens group)
5, 5', 5''	Lens (third lens group)
6	Lens (third lens group)
7	Glass filter
8	Aperture stop
D1-D14	Surface spacing on optical axis
R1-R15	Radius of curvature
S1-S15	Surface

Explanations in the drawings

Fig. 1, Fig. 7, Fig. 12

Object image

Image plane side

Image plane

Fig. 2, Fig. 8, Fig. 13

Image plane

Fig. 3

Image pickup device (image plane)

Fig. 4, Fig. 5, Fig. 6, Fig. 9, Fig. 10, Fig. 11, Fig. 14, Fig. 15, Fig. 16

Spherical aberration Sinusoidal condition (SC)

Astigmatism

Distortion (%)

Chromatic difference of magnification

Preferred embodiment

A preferred embodiment of the present invention is described below referring to the accompanying drawings.

Fig. 1 through Fig. 3 show a preferred embodiment of a zoom lens according to the present invention, wherein Fig. 1 shows its basic constitution, Figs. 2 (a) and (b) show a status of the positional relations at the pantoscopic and at the telescopic end, and Fig. 3 is a perspective view of the constitution.

In this zoom lens, a first lens group (I) that has a negative refractive power as a whole, a second lens group (II) that has a positive refractive power as a whole and a third lens group (III) that has a positive refractive power as a whole are laid out in that order from the objective side to the image plane side as shown in Fig. 1.

The first lens group (I) consists of a lens 1 that has a negative refractive power and a prism 2 that changes the light path. The second lens group (II) consists of a lens 3 that has a positive refractive power. The third lens group (III) consists of a lens 4 that has a positive refractive power, a lens 5 that has a negative refractive power, and a lens 6 that has a positive or negative refractive power.

The lenses and the prisms that constitute the first lens group (I), the second lens group (II), and the third lens group (III) are all made of resin materials. As they are made of resin materials, they can be built lighter and inexpensively.

In the above layout constitution, a glass filter 7 such as an infrared cut filter or a low pass filter is provided on the image plane side relative to lens 6 of the third lens group (III), and an aperture stop 8 is provided between the second lens group (II) and the third lens group (III), i.e., between lens 3 and lens 4. Since aperture 8 is located in the position as mentioned above, it is possible to make the lens groups arrange on both sides of it to have approximately equal outer diameters, thus reducing the size as a whole.

In the above constitution, the second lens group (II) and the third lens group (III) move from the image plane to the object side, in other words, from the pantoscopic end shown in Fig. 2(a) to the telescopic end as shown in Fig. 2(b) to perform the zooming operation as well as to correct the image plane change caused by the zooming operation. Since the depth dimension D of the lens and the lateral total length H of the lens (distance from prism 2 of the first lens group (I) to the image plane) are unchanged during the zooming operation, it can be easily mounted on cellular telephones, portable information terminals and the like where the mounting spaces are limited.

Let the focal distance of the first lens group (I) be denoted as f_1 , the focal distance of the total lens system at the pantoscopic end as fw , the focal distance of the total lens system at the telescopic end as ft , and the focal distance of the total lens system in the middle range as fm .

Also, let the surfaces of lens 1, prism 2, lens 3 through lens 6 be denoted as S_i ($i = 1-6, 8-13$), the radius of curvature of each surface S_i as R_i ($i = 1-6, 8-13$), the refractive ratio relative to line "d" as N_i , and the Abbe's number as v_i ($i = 1-6$) as shown in Fig. 1.

Also, as to glass filter 7, let the surfaces be denoted as S_i ($i = 14, 15$), the radius of curvature of surface S_i as R_i ($i = 14, 15$), the refractive ratio relative to line "d" as N_7 , and the Abbe's number as v_7 . Further, let each space (thickness, air gap) located between lens 1 and glass filter 7 along the optical axis be denoted as D_i ($i = 1-14$).

In prism 2, its entrance surface 2a and exit surface 2b are formed in rectangular shapes that are oblong in a direction perpendicular to a plane that contains entrance axis L1 and exit axis L2. In this case, the direction of the longer side of prism 2 and the direction of the longer side of image pickup device (image plane) coincide with each other as shown in Fig. 3. As a result, the depth dimension D in the entrance axis L1 direction of the first lens group (I), i.e., the zoom lens, can be reduced, thus making the unit thinner.

A surface S2 with a smaller radius of curvature between a surface S1 of the object side of lens 1 and surface S2 of image plane side is formed as an aspherical surface, wherein this aspherical surface is formed in such a way that its negative refractive power weakens toward the periphery. As a result, corrections of various aberrations, in particular, correction of distortion, can be achieved.

A surface S5 on the object side of lens 3, a surface S8 on the object side of lens 4, and a surface S12 on the object side of lens 6 are formed as aspherical surfaces. Consequently, various aberrations can be adjusted in a good balance, and aspherical aberrations can be corrected suitably, especially by forming surface S8 as an aspherical surface.

An aspherical surface can be expressed in the following formula:
 $Z=Cy^2/[1+(1-\epsilon C^2 Y^2)^{1/2}]+Dy^4+Ey^6+Fy^8+Gy^{10}$, where Z is the distance from the vertex of the aspherical surface to a point on the aspherical surface whose height from the optical axis is y; y is the height from the optical axis X; C is the ratio of curvature (1/R) at the vertex of the aspherical surface; ϵ is the conical constant, and D, E, F, G are aspherical coefficients.

In the above constitution, the first lens group (I) is formed to satisfy the following two formulas:

$$(1) \quad 0.25 < |fw/f1| < 0.7, \text{ and}$$

$$(2) \quad v_1 > 40,$$

where f_1 is the focal distance of the first lens group (I), f_w is the focal distance of the total lens system at the pantoscopic end, and v_1 is the Abbe's number of the lens of the first lens group (I).

The conditional formula (1) defines the ratio of an appropriate focal distance for the first lens group (I), where if the ratio exceeds the upper limit, the back focus becomes too large, so that it becomes difficult to make the unit smaller as well as to correct astigmatism and coma aberrations; on the other hand if it exceeds its lower limit, the refractive power of lens 1 becomes too small, so that it becomes difficult to secure a necessary back focus. In other words, it is possible to achieve a satisfactory optical capability and reduce the size of the unit by satisfying this conditional formula (I).

The conditional formula (2) defines the Abbe's number of lens 1 that constitutes the first lens group (I), where if it exceeds the lower limit, it becomes difficult to correct the chromatic difference of magnification. In other words, by satisfying the conditional formula (2), chromatic aberration of magnification can be corrected appropriately.

As an example using specific numerical values of the above embodiment, an embodiment 1 will be shown below. Table 1 shows the major dimensions of embodiment 1, Table 2 shows various numerical data (setup values), Table 3 shows numerical values of the aspheric surfaces, and Table 4 shows the focal distance of the lens as a whole "f" (pantoscopic end f_w , middle position f_m , and telescopic end f_t) as well as numerical data concerning the spacing between the surfaces on the axis D4, D6 and D13 at the pantoscopic end, middle position, and telescopic end specifically. In this example, the numerical data of the conditional formulas (1) and (2) are: $|f_w/f_1|=0.476$, $f_w=3.350$ mm, $f_1=-7.039$ mm, and $v_1=56.4$

Fig. 4, Fig. 5 and Fig. 6 are the aberration charts of spherical aberration, astigmatic aberration, distortion, and chromatic difference of magnification at the pantoscopic end, middle position, and telescopic end respectively. In Fig. 4 through Fig. 6, Fig. 9 through Fig. 11, and Fig. 14 through Fig. 16, "d" denotes the aberration due to "d" line, "F" denotes the aberration due to "F" line, and "c" denotes the aberration due to "c" line, while SC denotes the amount of dissatisfaction of the sinusoidal condition, DS denotes the aberration on the sagittal plane, and DT denotes the aberration of the meridional plane.

Table 1

Object distance (mm)	Infinity(∞)	Thickness of third lens group (mm)	7.20
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Focal distance (mm)	3.35～ 5.00～ 6.43	Total lateral length (prism to image plane) mm	25.28
F number	2.89～ 3.41～ 3.94	Back focus (air equivalent) (mm)	2.68～ 3.99～ 5.36
Total lens length (front of lens 1 to image plane) (mm)	28.23	Angle of view (2ω)	61.3°～ 40.0°～ 31.1°
Thickness of first lens group (depth) (mm)	7.75	Focal distance f_1 (mm)	-7.039
Thickness of second lens group (mm)	1.80	Pantoscopic end focal distance f_w (mm)	3.350

Table 2

Surface	Radius of curvature (mm)	Spacing (mm)	Refractive power ("d" line)	Abbe's number
S1	R1 -105.256	D1 1.250	N1 1.50914	v1 56.4
S2*	R2 3.725	D2 1.700		
S3	R3 ∞	D3 4.800	N2 1.58385	v2 30.3
S4	R4 ∞	D4 variable		
S5*	R5 14.566	D5 1.800	N3 1.50914	v3 56.4
S6	R6 -13.487	D6 variable		
S7	Aperture stop			
		D7 0.000		
S8*	R8 4.291	D8 2.500	N4 1.50914	v4 56.4
S9	R9 -27.904	D9 0.800		
S10	R10 -50.000	D10 1.500	N5 1.58385	v5 30.3
S11	R11 6.916	D11 0.900		
S12*	R12 12.944	D12 1.500	N6 1.50914	v6 56.4
S13	R13 14.260	D13 variable		
S14	R14 ∞	D14 1.200	N7 1.51680	v7 64.2
S15	R15 ∞			

* Aspheric

Table 3

Aspheric coefficient		Numerical data
S2 surface	ϵ	1.0278000
	D	-0.1581560 $\times 10^{-2}$
	E	0.1204590 $\times 10^{-3}$
	F	-0.5290880 $\times 10^{-5}$
	G	-0.1085100 $\times 10^{-5}$
S5 surface	ϵ	14.1500000
	D	0.9513050 $\times 10^{-4}$
	E	0.4852330 $\times 10^{-4}$
	F	-0.2827050 $\times 10^{-4}$
	G	-0.1499290 $\times 10^{-5}$
S8 surface	ϵ	0.0000000
	D	0.5818800 $\times 10^{-3}$
	E	0.7729490 $\times 10^{-4}$
	F	-0.2913690 $\times 10^{-5}$
	G	0.6163560 $\times 10^{-6}$
S12 surface	ϵ	1.0000000
	D	-0.6068020 $\times 10^{-2}$
	E	-0.6726320 $\times 10^{-5}$
	F	0.1080110 $\times 10^{-4}$
	G	-0.2055410 $\times 10^{-5}$

Table 4

	Pantoscopic end	Middle position	Telescopic end
f (mm)	3.35 (fw)	5.00 (fm)	6.43 (ft)
D4 (mm)	7.395	3.367	1.264
D6 (mm)	1.000	3.713	4.450
D13 (mm)	0.885	2.200	3.567

(Back focus 1.00 mm)

In the above embodiment 1, lens depth D (lens 1 to prism 2) is 7.75 mm, total lens length (prism to image plane) H is 25.28 mm, total lens length (front S1 of lens 1 to image plane) is 28.23 mm, back focus (air equivalent) is 2.68 mm - 3.99 mm - 5.36 mm, F number is 2.89 - 3.41 - 3.94, and angle of view (2ω) is $61.3^\circ - 40.0^\circ - 31.1^\circ$, thus providing a compact, thin, and a high optical capability lens with all aberrations suitably corrected.

Fig. 7 and Fig. 8 show the basic constitution of a zoom lens of another embodiment according to this invention. All components of this zoom lens are made of plastics (resins) and the zoom lens is constituted similarly to the above mentioned embodiment except the changes made in the specifications of lens 4', lens 5' and lens 6' of the third lens group (III).

As an example using specific numerical values of the above embodiment, an embodiment 2 will be shown below. Table 5 shows the major dimensions of embodiment 2, Table 6 shows various numerical data (setup values), Table 7 shows numerical values of the aspheric surfaces, and Table 8 shows the focal distance of the lens as a whole "f" (pantoscopic end fw, middle position fm, and telescopic end ft) as well as numerical data concerning the spacing between the surfaces on the axis D4, D6 and D13 at the pantoscopic end, middle position, and telescopic end specifically. In this example, the numerical data of the conditional formulas are: $|fw/f1|=0.476$, $fw=3.350$ mm, $f1=-7.039$ mm, and $v1=56.4$

Fig. 9, Fig. 10 and Fig. 11 are the aberration charts of spherical aberration, astigmatic aberration, distortion, and chromatic difference of magnification at the pantoscopic end, middle position, and telescopic end respectively.

Table 5

Object distance (mm)	Infinity (∞)	Thickness of third lens group (mm)	7.20
Focal distance (mm)	3.35～ 5.00～ 6.43	Total lateral length (prism to image plane) mm	25.39
F number	2.89～ 3.43～ 3.98	Back focus (air equivalent) (mm)	2.79～ 4.08～ 5.42
Total lens length (front of lens 1 to image plane) (mm)	28.34	Angle of view (2ω)	61.2°～ 39.9°～ 31.0°
Thickness of first lens group (depth) (mm))	7.75	Focal distance f1 (mm)	-7.039
Thickness of second lens group (mm)	1.80	Pantoscopic end focal distance fw (mm)	3.350

Table 6

Surface	Radius of curvature (mm)	Spacing (mm)	Refractive power ("d" line)	Abbe's number
S1	R1 -105.256	D1 1.250	N1 1.50914	v1 56.4
S2*	R2 3.725	D2 1.700		
S3	R3 ∞	D3 4.800	N2 1.58385	v2 30.3
S4	R4 ∞	D4 variable		
S5*	R5 14.566	D5 1.800	N3 1.50914	v3 56.4
S6	R6 -13.487	D6 variable		
S7	Aperture stop			
		D7 0.000		
S8*	R8 5.111	D8 2.500	N4 1.50914	v4 56.4
S9	R9 -33.812	D9 0.800		
S10	R10 12.088	D10 1.500	N5 1.58385	v5 30.3
S11	R11 5.889	D11 0.900		
S12*	R12 14.723	D12 1.500	N6 1.50914	v6 56.4
S13	R13 8.256	D13 variable		
S14	R14 ∞	D14 1.200	N7 1.51680	v7 64.2
S15	R15 ∞			

* Aspheric

Table 7

Aspheric coefficient		Numerical data
S2 surface	ϵ	1.1466000
	D	-0.2082540 $\times 10^{-2}$
	E	0.1196780 $\times 10^{-3}$
	F	-0.9545210 $\times 10^{-5}$
	G	-0.1047680 $\times 10^{-5}$
S5 surface	ϵ	31.6600000
	D	-0.6795480 $\times 10^{-3}$
	E	-0.1877220 $\times 10^{-3}$
	F	-0.1244610 $\times 10^{-4}$
	G	0.3063120 $\times 10^{-6}$
S8 surface	ϵ	-0.9200000
	D	0.1067690 $\times 10^{-2}$
	E	0.9841570 $\times 10^{-4}$
	F	-0.9494250 $\times 10^{-5}$
	G	0.8663850 $\times 10^{-6}$
S12 surface	ϵ	1.0000000
	D	-0.5542500 $\times 10^{-2}$
	E	0.8034850 $\times 10^{-4}$
	F	0.9776290 $\times 10^{-5}$
	G	0.1975590 $\times 10^{-5}$

Table 8

	Pantoscopic end	Middle position	Telescopic end
f (mm)	3.35 (fw)	5.00 (fm)	6.43 (ft)
D4 (mm)	7.395	3.434	1.379
D6 (mm)	1.000	3.669	4.390
D13 (mm)	0.998	2.289	3.624

(Back focus 1.00 mm)

In the above embodiment 2, lens depth D (lens 1 to prism 2) is 7.75 mm, total lens length (prism to image plane) H is 25.39 mm, total lens length (front S1 of lens 1 to image plane) is 28.34 mm, back focus (air equivalent) is 2.79 mm – 4.08 mm - 5.42 mm, F number is 2.89 - 3.43 - 3.98, and angle of view (2ω) is 61.2° – 39.9° – 31.0° , thus providing a compact, thin, and a high optical capability lens with all aberrations suitably corrected.

Fig. 12 and Fig. 13 show basic constitutions of zoom lens of other embodiments according to this invention. All components of this zoom lens are made of plastics (resins) and the zoom lens is constituted similarly to the above mentioned embodiment except the changes made in the specifications of lens 4", lens 5" and lens 6" of the third lens group (III).

As an example using specific numerical values of the above embodiment, an embodiment 3 will be shown below. Table 9 shows the major dimensions of embodiment 3, Table 10 shows various numerical data (setup values), Table 11 shows numerical values of the aspheric surfaces, and Table 12 shows the focal distance of the lens as a whole "f" (pantoscopic end fw, middle position fm, and telescopic end ft) as well as numerical data concerning the spacing between the surfaces on the axis D4, D6 and D13 at the pantoscopic end, middle position, and telescopic end specifically. In this example, the numerical data of the conditional formulas (1) and (2) are:

$$|fw/f1|=0.476, fw=3.350 \text{ mm}, f1=-7.039 \text{ mm}, \text{ and } v1=56.4$$

Fig. 14, Fig. 15 and Fig. 16 are the aberration charts of spherical aberration, astigmatic aberration, distortion, and chromatic difference of magnification at the pantoscopic end, middle position, and telescopic end respectively.

Table 9

Object distance (mm)	Infinity (∞)	Thickness of third lens group (mm)	7.20
Focal distance (mm)	3.35～ 5.00～ 6.43	Total lateral length (prism to image plane) mm	25.35
F number	2.89～ 3.43～ 3.97	Back focus (air equivalent) (mm)	2.75～ 4.04～ 5.37
Total lens length (front of lens 1 to image plane) (mm)	28.30	Angle of view (2ω)	61.1°～ 39.9°～ 31.0°
Thickness of first lens group (depth) (mm)	7.75	Focal distance f_1 (mm)	-7.039
Thickness of second lens group (mm)	1.80	Pantoscopic end focal distance f_w (mm)	3.350

Table 10

Surface	Radius of curvature (mm)	Spacing (mm)	Refractive power ("d" line)	Abbe's number
S1	R1 -105.256	D1 1.250	N1 1.50914	v1 56.4
S2*	R2 3.725	D2 1.700		
S3	R3 ∞	D3 4.800	N2 1.58385	v2 30.3
S4	R4 ∞	D4 variable		
S5*	R5 14.566	D5 1.800	N3 1.50914	v3 56.4
S6	R6 -13.487	D6 variable		
S7	Aperture stop			
		D7 0.000		
S8*	R8 4.696	D8 2.500	N4 1.50914	v4 56.4
S9	R9 93.726	D9 0.800		
S10	R10 10.987	D10 1.500	N5 1.58385	v5 30.3
S11	R11 6.348	D11 0.900		
S12*	R12 13.654	D12 1.500	N6 1.50914	v6 56.4
S13	R13 7.861	D13 variable		
S14	R14 ∞	D14 1.200	N7 1.51680	v7 64.2
S15	R15 ∞			

* Aspheric

Table 11

Aspheric coefficient		Numerical data
S2 surface	ϵ	1.1291000
	D	-0.1921580 $\times 10^{-2}$
	E	0.1173390 $\times 10^{-3}$
	F	-0.9858780 $\times 10^{-5}$
	G	-0.1009840 $\times 10^{-5}$
S5 surface	ϵ	32.1400000
	D	-0.5846820 $\times 10^{-3}$
	E	-0.1789410 $\times 10^{-3}$
	F	-0.1522010 $\times 10^{-4}$
	G	0.3046050 $\times 10^{-6}$
S8 surface	ϵ	-0.5500000
	D	0.1140500 $\times 10^{-2}$
	E	0.8869180 $\times 10^{-4}$
	F	-0.7484270 $\times 10^{-5}$
	G	0.1166400 $\times 10^{-5}$
S12 surface	ϵ	1.0000000
	D	-0.6099420 $\times 10^{-2}$
	E	0.6410210 $\times 10^{-4}$
	F	0.8377440 $\times 10^{-5}$
	G	0.1930490 $\times 10^{-5}$

Table 12

	Pantoscopic end	Middle position	Telescopic end
f (mm)	3.35 (fw)	5.00 (fm)	6.43 (ft)
D4 (mm)	7.395	3.443	1.394
D6 (mm)	1.000	3.663	4.382
D13 (mm)	0.957	2.245	3.575

(Back focus 1.00 mm)

In the above embodiment 3, lens depth D (lens 1 to prism 2) is 7.75 mm, total lens length (prism to image plane) H is 25.35 mm, total lens length (front S1 of lens 1 to image plane) is 28.30 mm, back focus (air equivalent) is 2.75 mm – 4.04 mm - 5.37 mm, F number is 2.89 - 3.43 - 3.97, and angle of view (2ω) is 61.1° – 39.9° – 31.0° , thus providing a compact, thin, and a high optical capability lens with all aberrations suitably corrected.

What is claimed is:

1. A zoom lens comprising: a first lens group having a negative refractive power as a whole, a second lens group having a positive refractive power as a whole, and a third lens group having a positive refractive power as a whole, arranged in said order from object side to image plane side, for zooming from a pantoscopic end to a telescopic end as well as for correcting image plane changes required in accordance with said zooming by means of moving said second lens group and said third lens group from image plane side to objection side; wherein

said first lens group consists of a lens having a negative refractive power and a prism for changing a light path arranged in said order from the object side.

2. A zoom lens claimed in claim 1 wherein,

said second lens group consists of a lens having a positive refractive power; and

an aperture stop is provided between said second lens group and said third lens group.

3. A zoom lens claimed in claim 1 or claim 2 wherein,

said first lens group's lens has an aspherical surface.

4. A zoom lens claimed in claim 3 wherein,

said aspherical surface is formed on a surface with a smaller radius of curvature.

5. A zoom lens claimed in claim 4 wherein,

said aspherical surface is formed to have a weaker negative refractive power weakening toward its periphery.

6. A zoom lens claimed in either one of claim 1 through claim 5 wherein,

said third lens group has at least one lens with a positive refractive power and at least one lens with a negative refractive power.

7. A zoom lens claimed in claim 6 wherein,

said third lens group has a lens at a position closest to the object having a positive refractive power and an aspherical surface at least on one side.

8. A zoom lens claimed in either one of claim 1 through claim 7 wherein,

the prism of said first lens group is formed to have an entrance surface and an exit surface both oblong in a direction perpendicular to a plane that includes an entrance axis and an exit axis.

9. A zoom lens claimed in either one of claim 1 through claim 8 that satisfies the following equations (1) and (2):

$$(1) \quad 0.25 < |fw/f1| < 0.7, \text{ and}$$

$$(2) \quad v1 > 40,$$

where $f1$: focal distance of the first lens group,

fw : focal distance of the total lens system at the pantoscopic end, and

$v1$: Abbe's number of the first lens group's lens

10. A zoom lens claimed in either one of claim 1 through claim 9 wherein, said first, second, and third lens groups are all made of resin materials.

Abstract

The present invention can provide a small, thin, light and low cost zoom lens suitable for cellular telephones, portable information terminals, etc.

In particular, it can provide a small and thin, high performance zoom lens having a zoom ratio of approximately 2, a depth of less than 9 mm in shooting and storage, a total lens length of less than 29 mm, an angle of view of approximately 61°, and a F number of 2.8 or higher providing a sufficient light, with various aberrations all suitably corrected.